

2008 WMA Mini-Grant Research Project Proposal

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This project is in affiliation with what WMA group or groups?

Yes

List what other Noxious and Invasive Weed Research has been conducted by you or your group:

Dr. Valerie Eviner, lead researcher, has conducted the following noxious and invasive weed research:

- 1) Impact of medusahead and goatgrass on soil conditions, compared to other California native and exotic grassland plants.
- 2) Interactions between gophers and fungi in goatgrass establishment.
- 3) Timing, quantity, and type of soil resource use by medusahead, goatgrass, and yellow starthistle, compared to other California native and exotic grassland plants.
- 4) Competitive dynamics between goatgrass, medusahead, and other California grassland plants, and how those competitive dynamics are altered by grazing, precipitation shifts, and nitrogen deposition.

Proposed Project(s)

Project Title: Restoring Soil Conditions to Enhance Native Grassland Resistance to Weed Invasion

Project Goal (1/2 page max):

Despite aggressive weed management, many grassland restoration projects in the Central Valley and surrounding foothills fail because they are inevitably invaded by weeds. A large portion of invasion research has focused on restoring specific plant species or combinations of species to enhance plant community resistance (Crawley et al. 1999, Levine and D'Antonio 1999, Naeem et al. 2000., Foster et al. 2002, Knight and Reich 2005, Emery and Gross 2007), but the key component of resistance may be the soil conditions. Scientists are increasingly recognizing that plant-soil interactions play critical roles in determining the invasiveness of weeds in plant communities (Klironomos 2002, Blank and Sforza 2006, Kulmatiski et al. 2006). For example, in experimental plots Kulmatiski et al. (2006) found that the invasiveness of diffuse knapweed (*Centaurea diffusa*) and cheatgrass (*Bromus tectorum*) depends more on soil conditions from past land uses than on competition from neighboring native plants. Evidence is quickly mounting that weeds can actively alter soil conditions to favor themselves over other species (Callaway and Aschehoug 2000, Hawkes et al. 2005, Wolf and Klironomos 2005, Batten et al. 2008). For example, barbed goatgrass (*Aegilops triuncialis*) may be invasive because it negatively affects the performance of desirable plants by both changing the soil microbial community composition and slowing C and N cycling rates due to its low quality litter (Drenovsky and Batten 2007, Batten et al. 2008). Altered soil conditions can last long after the weed is removed (Hawkes et al. 2005), which suggests that reversing the impacts of weeds on soil may be a critical step in developing (or restoring) grasslands that resist invasion by weeds.

The goals for this pilot project are to determine:

1) Does medusahead (*Taeniatherum caput-medusae*) alter soil conditions to favor its success over desirable species?

Determining if medusahead alters soil conditions to favor itself will help to determine if soil conditions are a key component of its invasiveness, and if soil restoration would enhance resistance to invasion. For example, compared to desirable California grassland species, medusahead can utilize soil moisture at greater depths later into the growing season (Clausnitzer et al. 1999), and N both earlier and later in the growing season (Eviner, personal communication) at different depths throughout the growing season (James et al. 2008). This may indicate that medusahead changes the spatial distribution of soil resources and the timing of resource fluxes from the conditions that favor desirable species.

2) Which soil conditions are key to favoring medusahead over desirable species, and how can these be restored to benefit desirable species? Knowing which soil conditions favor medusahead will help to develop management techniques for restoring the soil, such as adding fertilizer, using chemicals to inhibit soil processes, adding/ removing litter, tilling to mix the soil profile, inoculating with certain soil microbes, or modifying soil with other plants. Similar soil modifying techniques have been used to control medusahead. Young et al. (1998) decreased medusahead establishment in experimental plots by treating the seed bank with nitrification inhibiting chemicals, and suggested conducting field trials with desirable plant species that can be maintained and grown under low levels of N to discover N levels that suppress medusahead establishment.

What are the project's long-term benefits and/or local, regional or statewide significance (8 sentence Max):

This project investigates a potentially critical and often overlooked component of the ultimate long-term weed prevention strategy: creating weed-resistant plant communities. If this study suggests that medusahead alters soil conditions to favor itself over desirable species, then restoring soil conditions could be a key strategy to restoring weed-resistant grasslands. On the other hand, if this study suggests that medusahead does not favor itself by altering soil conditions, then managers and restoration practitioners can focus on exploring other mechanisms of prevention, such as controlling propagule dispersal. By exploring how medusahead interacts with soil, this project could ultimately inform the development of management techniques that restore soil conditions in California grasslands that promote resistance to weeds. . By working in collaboration with the Yolo WMA and land managers in Yolo County, the management techniques that are explored will be feasible, useful, and effective. Enhancing the resistance of restored grasslands to medusahead would be a highly effective long- term method of weed control. Restoring weed- resistant grasslands would help to stop or slow the regional spread of medusahead, contributing to regional eradication efforts.

Priority Topic Area Being Addressed (from request for proposal announcement, 8 sentence Max):

This project addresses Priority Topic Area #3 Restoration, and focuses on a CDFA "C- rated" weed, medusahead. This project focuses on medusahead because it is extremely prevalent in several restored grasslands in the Central Valley. Many land managers have expressed concern for its propensity to reinvade restoration sites, and the importance of medusahead-soil interactions in shaping plant communities is yet to be explored.

This project involves visiting restoration sites and studying the site history, initial establishment methods and the current distributions of invasive and native plants. It is heavily focused on determining if plant-soil interactions are essential to restoring weed-resistant grasslands, and ultimately on developing management techniques to restore grasslands that are resistant to invasion and contain a diversity of desirable species.

The quality, scientific merit, and local significance of this project will be ensured through field visits by Tanya Meyer (Yolo County RCD/Yolo Weed Management Area) and staff from Audubon California's Landowner Stewardship Program, as well as field and laboratory advising by Dr. Valerie Eviner (UC Davis).

Please Describe your in-kind contributions toward research project(s) (4 sentence max):

All field and laboratory work, analyses, and dissemination of results will be completed by Sarah Hoskinson, whose stipend, student fees, and benefits will be funded from a UC Davis Plant Sciences Graduate Student Researcher appointment and a grant from the Kearny Foundation (\$28,089 total) for the duration of this grant. Additional funding for processing soil samples and transportation to the field are provided by a UC Davis Graduate Group in Ecology Jastro-Shields Fellowship (\$1,200) and the UC Davis Plant Sciences Department Scholarship (\$800). All field and laboratory equipment is provided by Dr. Valerie Eviner.

Project Objectives, Tasks and Methods:

OVERALL OBJECTIVE (4 sentence Max): To determine 1) if medusahead alters soil conditions to favor itself over commonly used native grass species; 2) what those soil conditions are; and 3) to utilize information from this study to develop new or refine existing management techniques that promote weed resistant grassland soils. Results may be considered for applicability to other invasive species.

Task 1 (2 sentence Max): Track soil changes through time in medusahead, native bunchgrass and annual grass patches.

Methods (8 sentence Max)- This task will be addressed by two separate studies: 1) In a four-year old grassland restoration project (on Audubon California's Bobcat Ranch in Winters) patches of medusahead were delineated from non-invaded areas, which are colonized mostly by purple needlegrass (*Nasella pulchra*), in spring 2008. The expansion of the medusahead patches and changes to the previously un-invaded soil will be tracked through time. Soil cores will be taken in multiple seasons and at several depths to analyze the soil for available N and P, pH, organic matter, and moisture, which are

resources that are critical for plant growth in California grasslands (Jones et al. 1983, Heady et al. 1991) and that have often been shown to be altered by other weed species (Ehrenfeld 2003, Chapuis-Lardy et al. 2006, Vinton and Goergen 2006).

2) Experimental plots of medusahead, common native perennial grass species, and common annual grass species were established on the UC Davis campus in a fallow field by Dr. Eviner's lab in fall 2007. Soil samples were taken prior to the establishment of these plots, and will be compared to soil samples taken through time and analyzed for resources to determine if medusahead alters the soil conditions, and how these alterations compare to those by other species.

Task 2 (2 sentence Max): Study differences in germination and competitive interactions of medusahead versus native grass species in soils taken from medusahead or native grass patches.

Methods (8 sentence Max)- The effects of soil that is cultured by medusahead on the germination and competitive outcome of medusahead versus desirable grass species will be studied. Soils from medusahead and purple needlegrass patches will be used to plant equal numbers of propagules of medusahead (collected from Bobcat Ranch in spring 2008) and purple needlegrass. The number of existing propagules in the field soil will be counted before beginning the experiment. Germination and establishment rates will be compared to determine if soil cultured by medusahead leads to greater germination and establishment rates of medusahead than purple needlegrass.

Transplanted plugs of medusahead and purple needlegrass will be used in the same experimental setup, except growth and survivorship rates will be compared in order to explore competitive interactions during other growth stages. The same experimental setups will also be used to compare the effects of medusahead soil on the germination and growth of other desirable grass species that were planted in the restored area at Bobcat Ranch, such as blue wildrye (*Elymus glaucus*) and meadow barley (*Hordeum brachyantherum*). The greenhouse experiment will run for the duration of this grant.

Task 3 (2 sentence Max): Utilize information from Task 1 to design studies of soil characteristics key to medusahead competitiveness and amenable to management practice alteration.

Methods (8 sentence Max)- Determining which soil conditions are key to favoring medusahead will involve teasing apart the effects of the soil conditions that medusahead alters in Task 1 on the germination and establishment of desirable species propagules as compared to medusahead propagules. This will initially involve greenhouse trials using soil taken from beneath medusahead in the field, and eventually field trials. For example, if medusahead is found to change the depth at which N is available in the soil profile (Task 1), invaded soil profiles and "restored" profiles with different locations of N could be reconstructed and the effects on medusahead versus desirable species propagules could be compared. Understanding which soil conditions are most critical for favoring medusahead will help to start experimenting with management tools, such as adding fertilizer, using chemicals to inhibit soil processes, adding/ removing litter, tilling to mix the soil profile, inoculating with certain soil microbes, or modifying soil with other plant species. The greenhouse trials will begin in fall 2009 as soon as the annual seasonal change soil data is analyzed in Task 1.

Performance Measures:

How will you assess and/or analyze your results (8 sentence Max)?

Task 1: Study 1) Determining if medusahead changes the amount, timing, and form of soil resource availability will be assessed by comparing the differences in soil conditions between the invaded patches and non-invaded areas. The relationships between the site histories (past invasions and land uses, the methods that were initially used to establish the restoration area, and all management since restoration) and the soil conditions in the invaded versus non-invaded areas will also be assessed. The medusahead patches will be monitored at the same time points as the soil sampling (see below) but beginning in fall 2008, and their expansion will be assessed using photos and by markings in the field.

Study 2) Soil conditions before and after planting will be assessed using paired t-tests and ANOVAs to compare medusahead versus other species soil conditions.

For both Task 1 studies, soil samples will be collected and analyzed using ANOVAs at key time points for plant uptake (winter 2009, early spring 2009, late spring 2009, and fall 2009), and seasonal change data from the entire year will be analyzed soon after the fall 2009 time point.

Task 2: T-tests will be used to compare the germination and establishment rates of propagules grown in soil cultured by medusahead versus purple needlegrass/ blue wildrye/ meadow barley/ other species. T-tests will also be used to compare the growth and survivorship of plugs grown in soil cultured by medusahead versus purple needlegrass/ blue wildrye/ meadow barley/ other species.

Task 3: Germination and establishment rates of medusahead versus other species on invaded and constructed “restored” soil conditions will be analyzed using paired t-tests..

The ultimate usefulness of this study will be determined through field trials with landowners and managers in the development and/or refinement of management techniques.

How will your results be disseminated (4 sentence Max)?

The results will be disseminated in articles that will be submitted to CDFA, invasive weed newsletters, SERCAL newsletters, and peer-reviewed journals. The results will be presented at the 2009 WMA statewide meeting, Yolo County WMA meetings, the 2009 Cal-IPC meeting, and the 2009 Ecological Society of America meetings.

Literature Cited:

- Batten, K. M., K. M. Scow, E. K. Espeland. 2008. Soil microbial community associated with an invasive grass differentially impacts native plant performance. *Microbial Ecology* 55:220-228.
- Blank, R. R. and R. Sforza. 2007. Plant-soil relationships of the invasive annual grass *Taeniatherum caput-medusae*: a reciprocal transplant experiment. *Plant and Soil* 298:7-19.
- Callaway, R. M. and E. T. Aschehoug. 2000. Invasive plants versus their old and new neighbors: a mechanism for exotic invasion. *Science* 290:521-523.
- Chapuis-Lardy, L. S. Vanderhoeven, N. Dassonville, L. S. Koutika, and P. Meerts. 2006. Effect of the exotic invasive plant *Solidago gigantea* on soil phosphorus status. *Biology and Fertility of Soils* 42:481-489.
- Clausnitzer, D. W., M. M. Borman, D. E. Johnson. 1999. Competition between *Elymus elymoides* and *Taeniatherum caput-medusae*. *Weed Science* 47:470-478.
- Crawley, M. J., S. L. Brown, M. S. Heard, and G. R. Edwards. 1999. Invasion-resistance in experimental grassland communities: species richness or species identity? 2:140-148.
- Drenovsky, R. E. and K. M. Batten. 2007. Invasion by *Aegilops triuncialis* (barbed goatgrass) slows carbon and nitrogen cycling in serpentine grassland. *Biological Invasions* 9:107-116.
- Ehrenfeld, J. G. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. *Ecosystems* 6:503-523.
- Emery, S. M. and K. L. Gross. 2007. Dominant species identity, not community evenness, regulates invasion in experimental grassland plant communities. *Ecology* 88:954-964.
- Foster, B. L., V. H. Smith, T. L. Dickson, and T. Hildebrand. 2002. Invasibility and compositional stability in a grassland community: relationships to diversity and extrinsic factors. *Oikos* 99:300-307.
- Hawkes, C. V., I. F. Wren, D. J. Herman, and M. K. Firestone. 2005. Plant invasion alters nutrient cycling by modifying the soil nitrifying community. *Ecology Letters* 8:976-985.
- Heady, H. F., J. W. Bartolome, M. D. Pitt, M. G. Stroud, and G. D. Savelle. 1991. California prairie. Pages 313-335 in R. T. Coupland, editor. *Natural grasslands. Ecosystems of the World. Volume 8A.* Elsevier Scientific, New York.
- James, J. J., K. W. Davies, R. L. Sheley, and Z. T. Aanderud. 2008. Linking nitrogen partitioning and species abundance to invasion resistance in the Great Basin. *Oecologia* 156:637-648.
- Jones, M. B., W. A. Williams, and C. E. Vaughn. 1983. Soil characteristics related to production on subclover-grass range. *Journal of Range Management* 36:444-446.
- Klironomos, J. N. 2002. Feedback with soil biota contributes to plant rarity and invasiveness in communities. *Nature* 417:67-70.
- Knight, K. S. and P. B. Reich. 2005. Opposite relationships between invasibility and native species richness at patch versus landscape scales. *Oikos* 109:81-88.
- Kulmatiski, A., K. H. Beard, and J. M. Stark. 2006. Soil history as a primary control on plant invasion in abandoned agricultural fields. *Journal of Applied Ecology* 43:868-876.

- Levine, J. M. and C. M. D'Antonio. 1999. Elton revisited: a review of evidence linking diversity and invasibility. *Oikos* 87:15-26.
- Naeem, S., J. M. H. Knops, D. Tilman, K. M. Howe, T. Kennedy, and S. Gale. 2000. Plant diversity increases resistance to invasion in the absence of covarying extrinsic factors. *Oikos* 91:97-108.
- Vinton, M. A. and E. M. Goergen. 2006. Plant-soil feedbacks contribute to the persistence of *Bromus inermis* in tallgrass prairie. *Ecosystems* 9:967-976.
- Wolfe, B. E. and J. N. Klironomos. 2005. Breaking new ground: soil communities and exotic plant invasion. *Bioscience* 55:477-487.
- Young, J. A., J. D. Trent, R. R. Blank, D. E. Palmquist. 1998. Nitrogen interactions with medusahead (*Taenitherum caput-medusae ssp. asperum*) seedbanks. *Weed Science* 46:191-195.